ECONOMIC OPERATION OF POWER SYSTEMS

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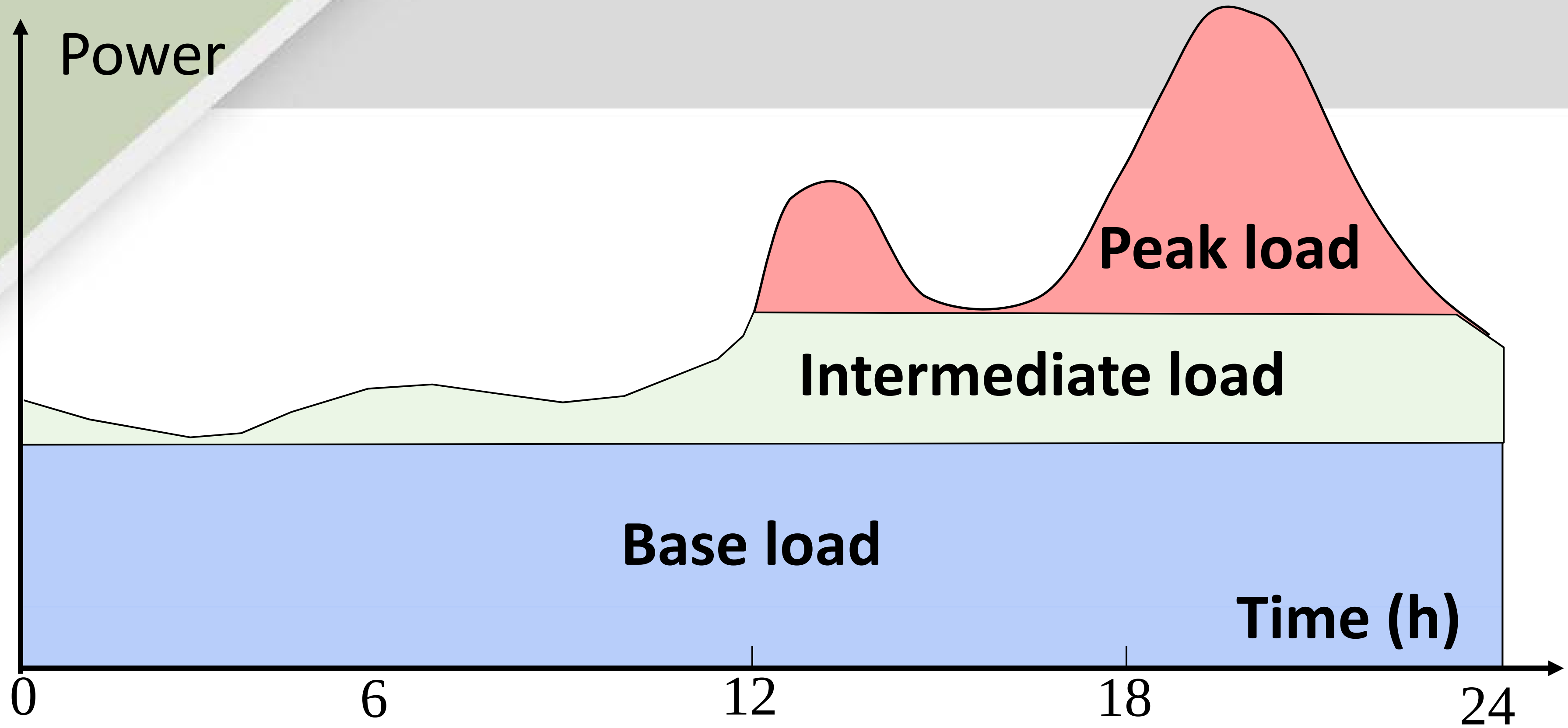
Base load and peak load

- In the case of using only one power plant, the capacity of the power generation will be defined according to the peak value
- The plant will operate at a part of load for prolonged time, which decreases the efficiency
- Several smaller units are installed with some of them covering base load and others covering peak load
- The units that cover the base load operate continuously, while those taking the peak load operate when required
- All units operate near their rated power with high efficiency

Base load and peak load



- base load has almost unvarying value
- intermediate load varies within certain limits
- peak load vary randomly

Base load and peak load

The generating units that operate as base power plants should have the following characteristics:

- Low operating cost since they operate continuously
- High capability of operating continuously for long time
- Low and fast maintenance requirements
- The load factor is very high and reaches unity for many units

Thermal, nuclear and hydraulic power plants are conventionally considered as base load plants

Base load and peak load

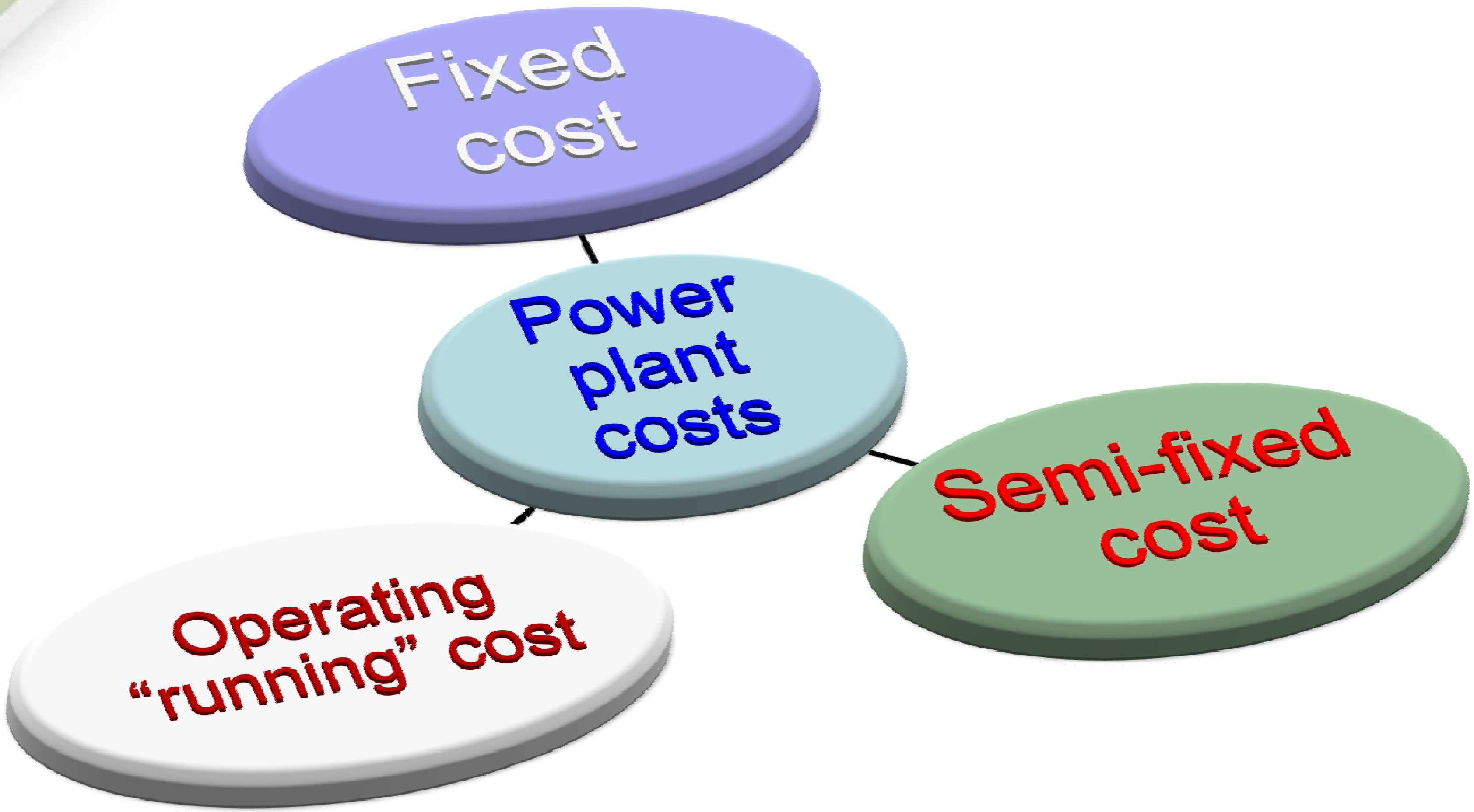
The units that operate as peak power plants should have the following characteristics:

- Very fast response to load variation (high ramp rate)
- Low start up time
- Low start up cost
- Low capital cost for economic operation since they operate for relatively short time during the year
- Constant voltage and frequency against the load fluctuations
- The load factor is very low in the range of 0.1-0.6

Steam, gas turbine and diesel power plants are used as peak power plants.

Economic analysis of power plants

Classification of power-plant costs



Classification of power-plant costs

Fixed cost

- The capital invested in the installation of the entire plant
- Independent of the output energy and maximum demand
- Represents a constant annual cost for the power plant
- Includes: the cost of land, buildings, equipments, transmission and distribution lines with all infrastructures and the cost of planning and designing the plant

Classification of power-plant costs

Operating or running cost

- Depends on the number of operating hours of the power plant and on the output energy
- Includes the annual fuel cost, lubricating oil, cooling water, maintenance cost and repair and employees' payments
- Approximately proportional to the output energy
- The consumption of fuel rate varies depending on the percentage loading and it has a minimum value at full load

Classification of power-plant costs

Semi-fixed cost

- Independent of the output energy
- Depends on the maximum demand
- Includes the *annual interest, depreciation on the investment capital cost, taxes and insurance*
- Almost proportional to the maximum demand

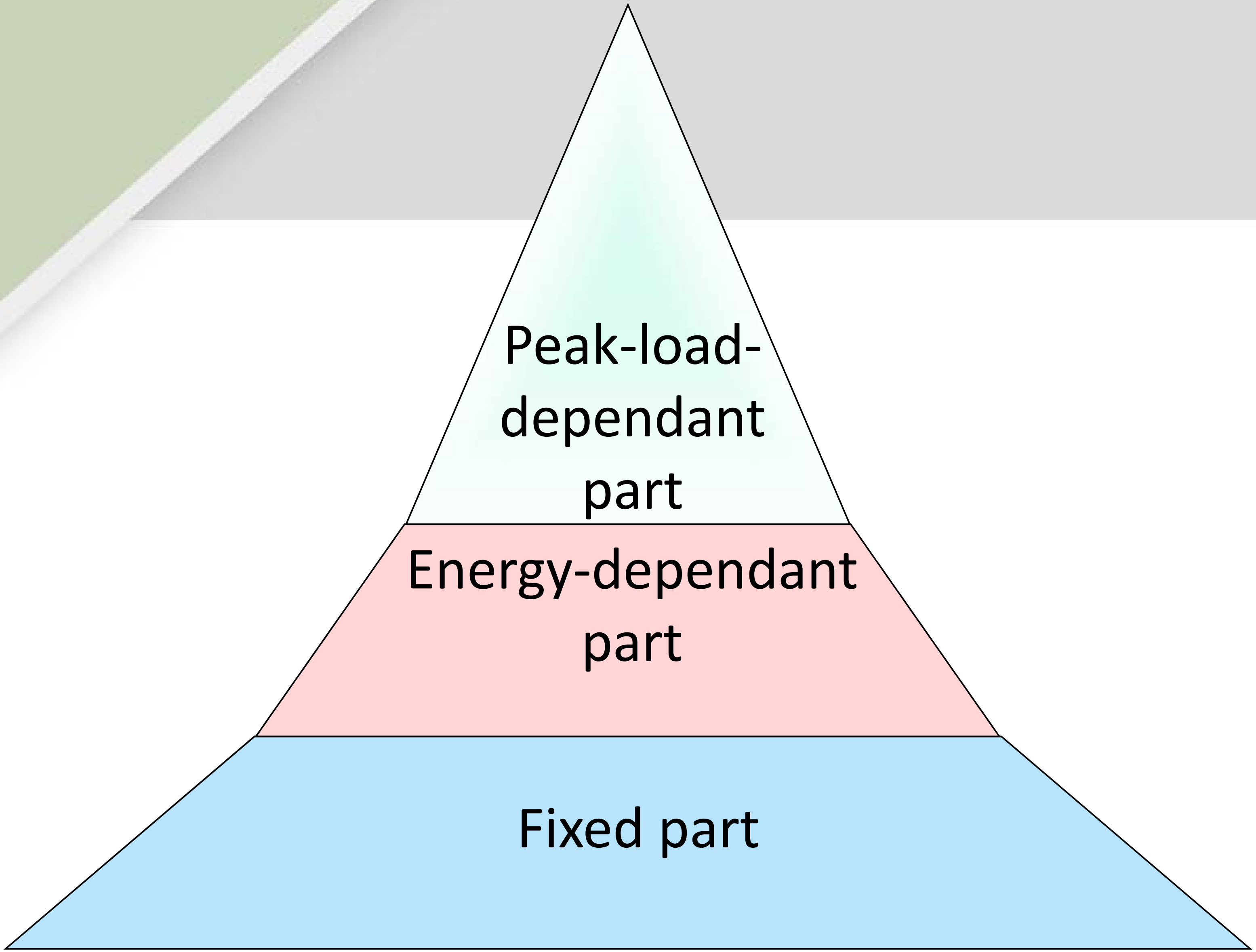
Classification of power-plant costs

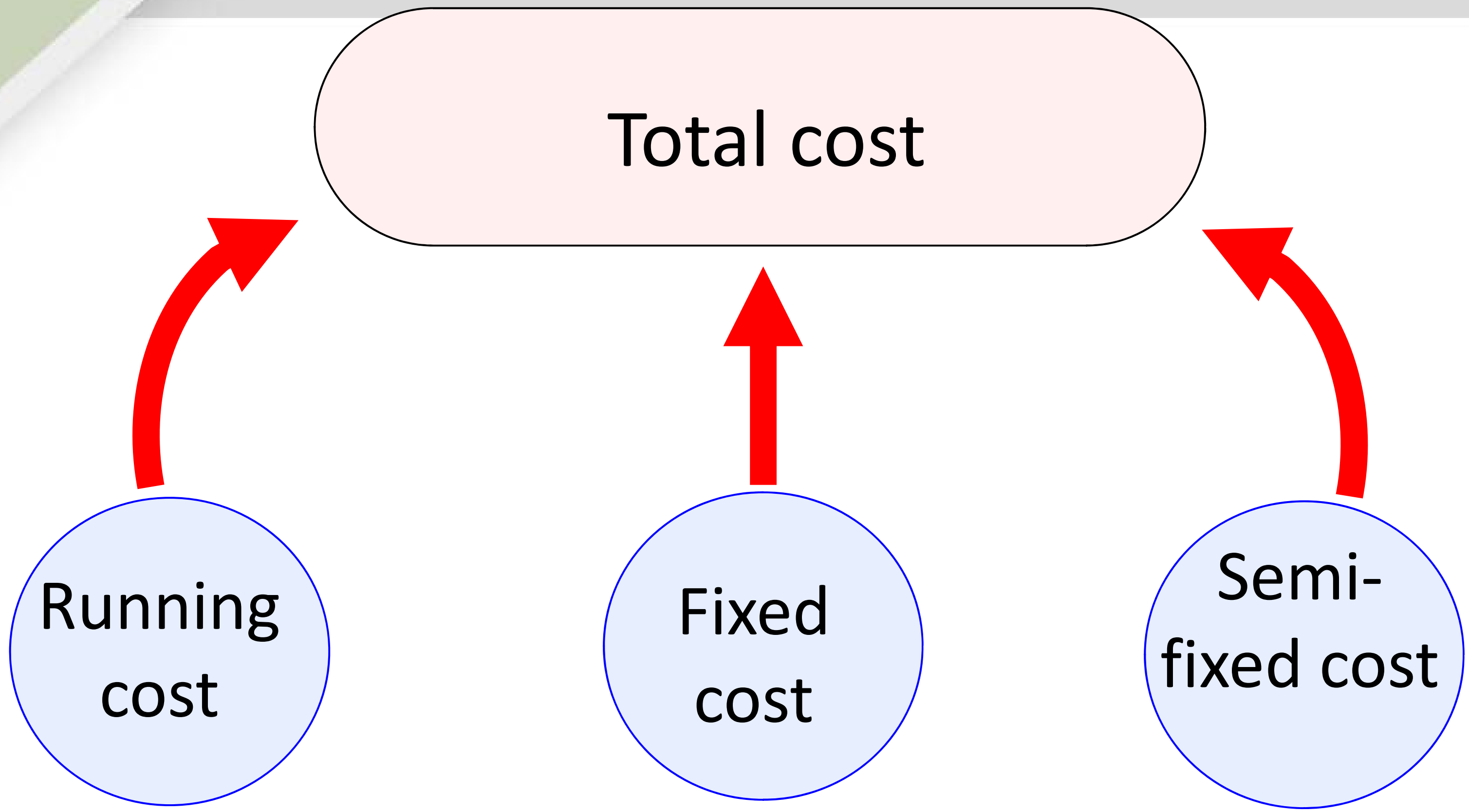
The total annual cost of energy produced in a power plant is the sum of the three costs:

$$Z = a \,.\, P + b \,.\, E + c$$

P is the average generated power (kW)
E is the annual energy (kWh)
a, b and c are constants

The designer attempts to minimize the total annual cost of the plant by the proper choice of the plant type and suitable distribution of power on the different power plants


Peak-load-dependant part
Energy-dependant part
Fixed part


Total cost
Running cost
Fixed cost
Semi-fixed cost

Interest

Big projects are financed using borrowed money and hence, the interest on the capital investment must be considered

If the money is not borrowed, the interest has to be considered to account for the profit that would be obtained if the money were invested in other projects

Depreciation cost

The depreciation cost represents the annual cost required to the depreciation caused by wear and tear of equipments and machines because of the **normal operation**

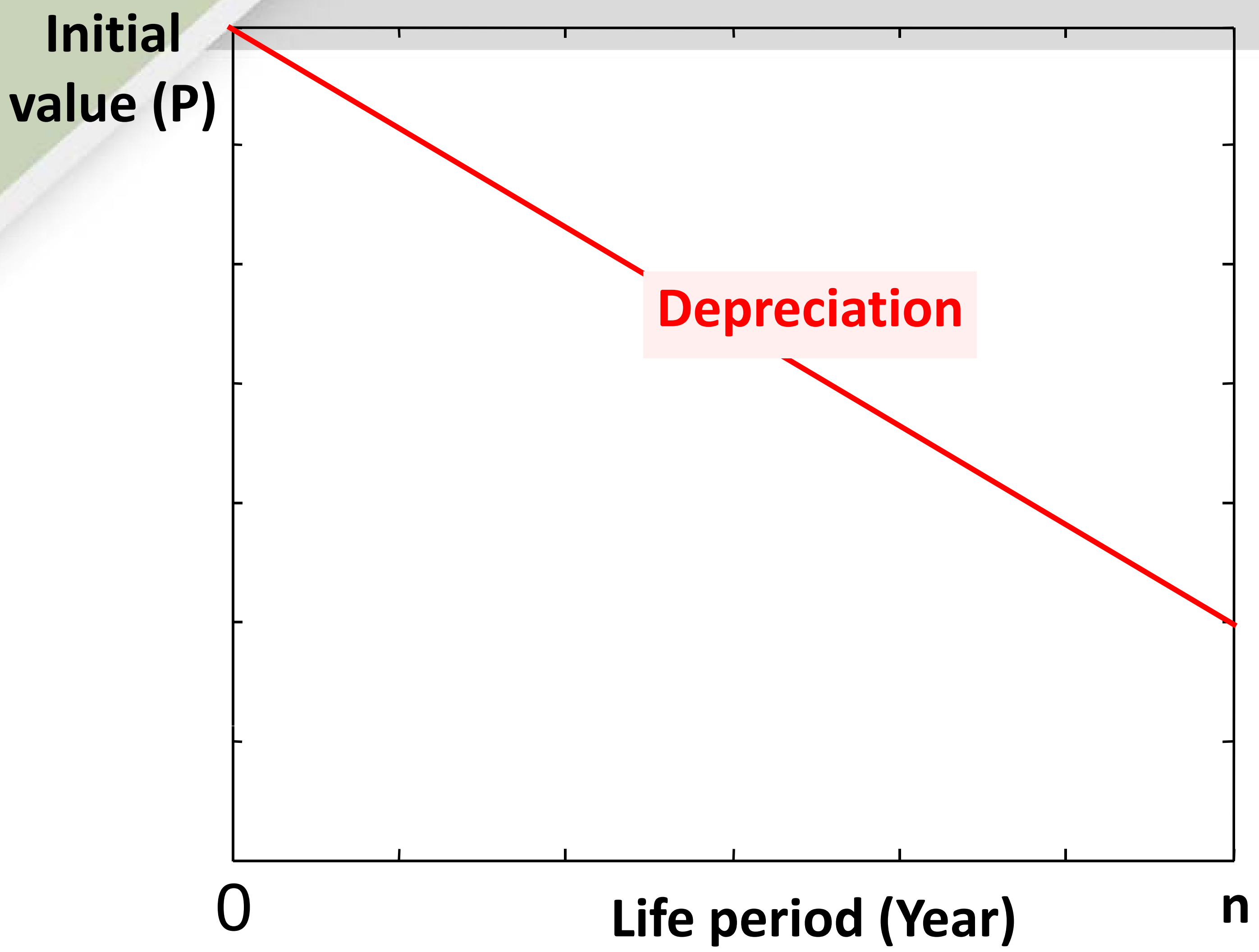
The equipments and machines have to be replaced after a certain time known as the operating life

It is necessary then to get aside certain amount of the income to collect sufficient money that is equal to the capital invested in these machines and equipments

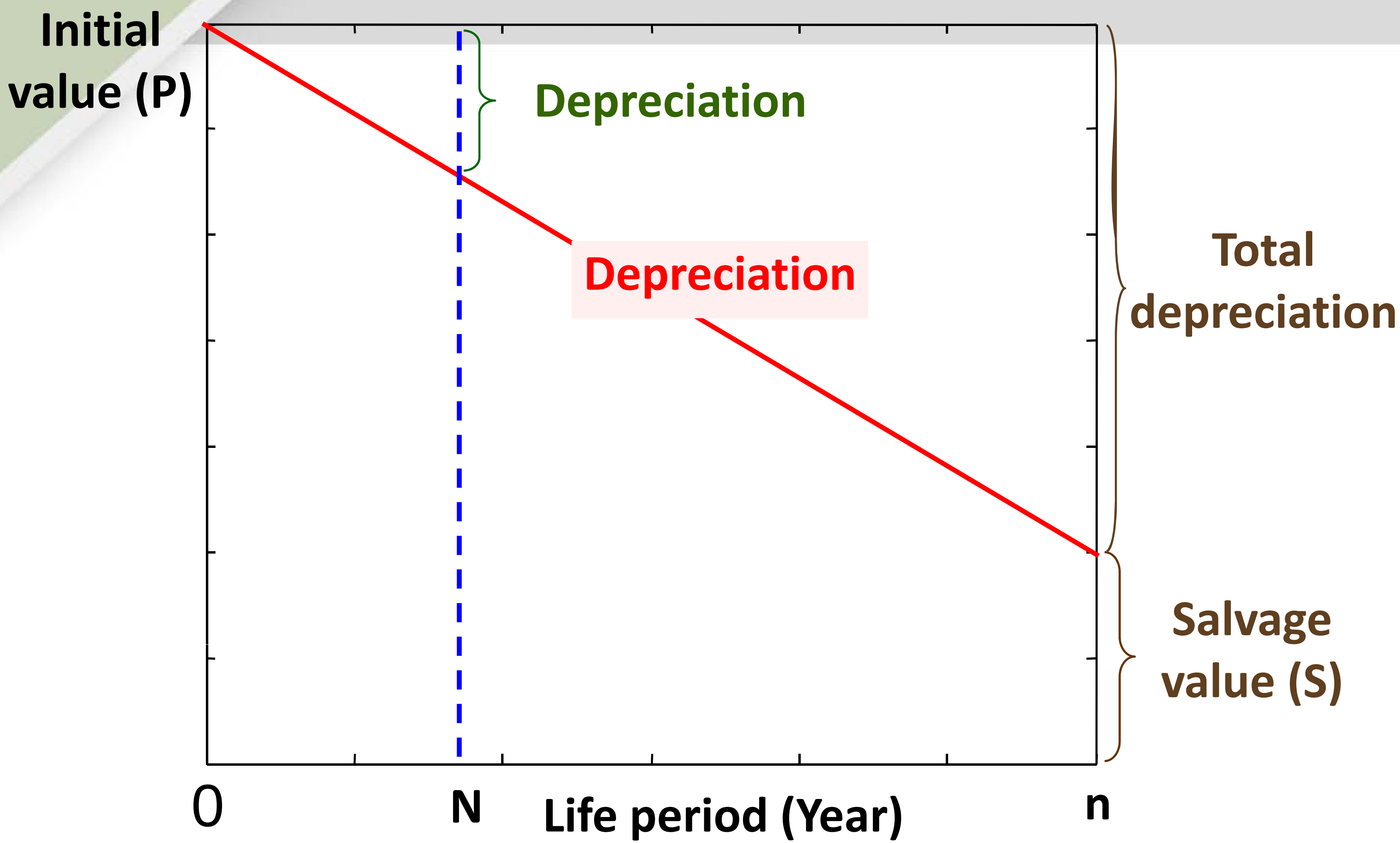
Depreciation cost

- **P** — Initial investment value of all equipments (capital cost)
- **S** — Salvage value at the end of the life time (Scrap value)
- **n** — Life of the equipments in years
- **A** — Set aside money per year
- **r** — Annual rate of compound interest
- **x** — Annual unit depreciation

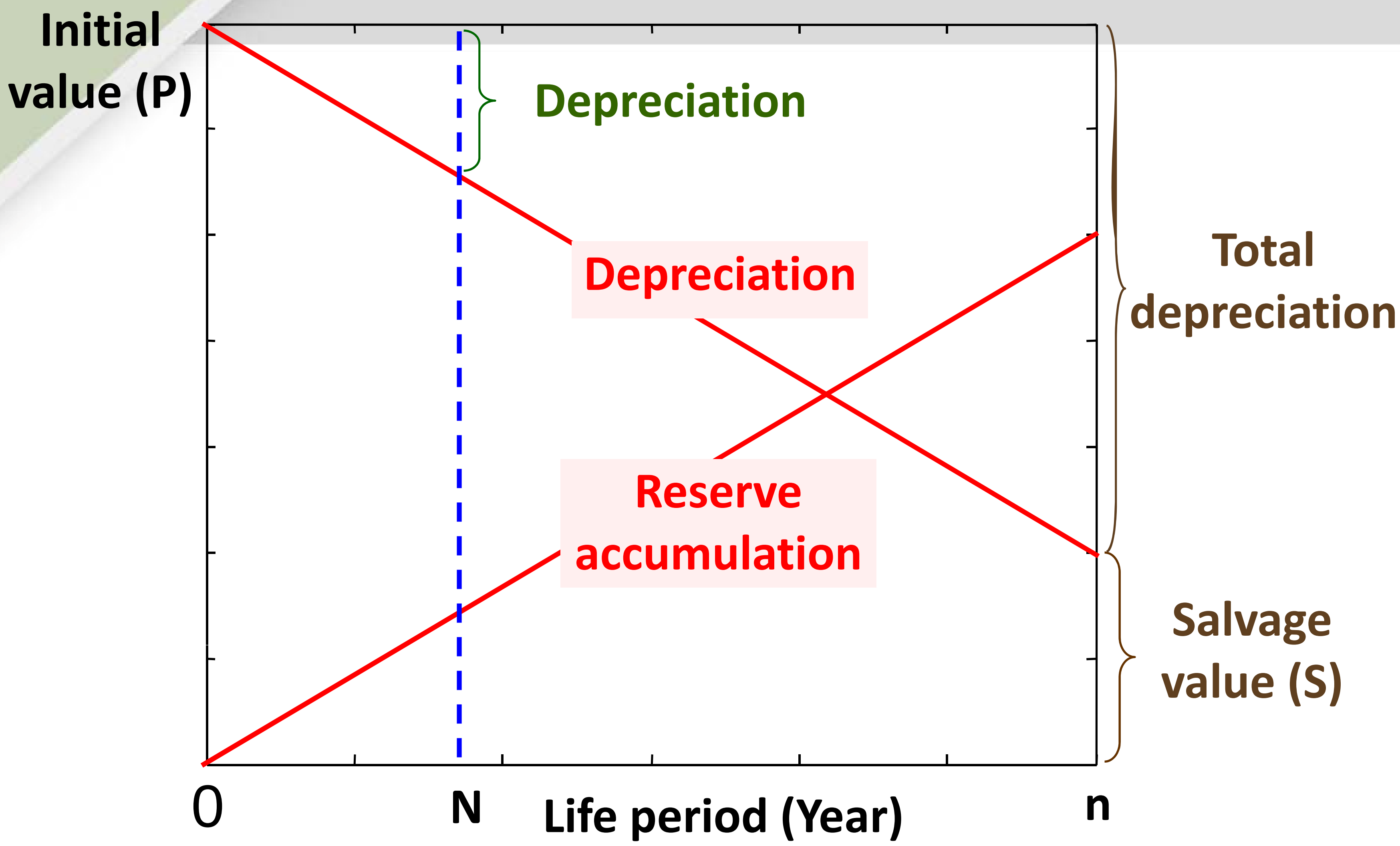
Straight line method



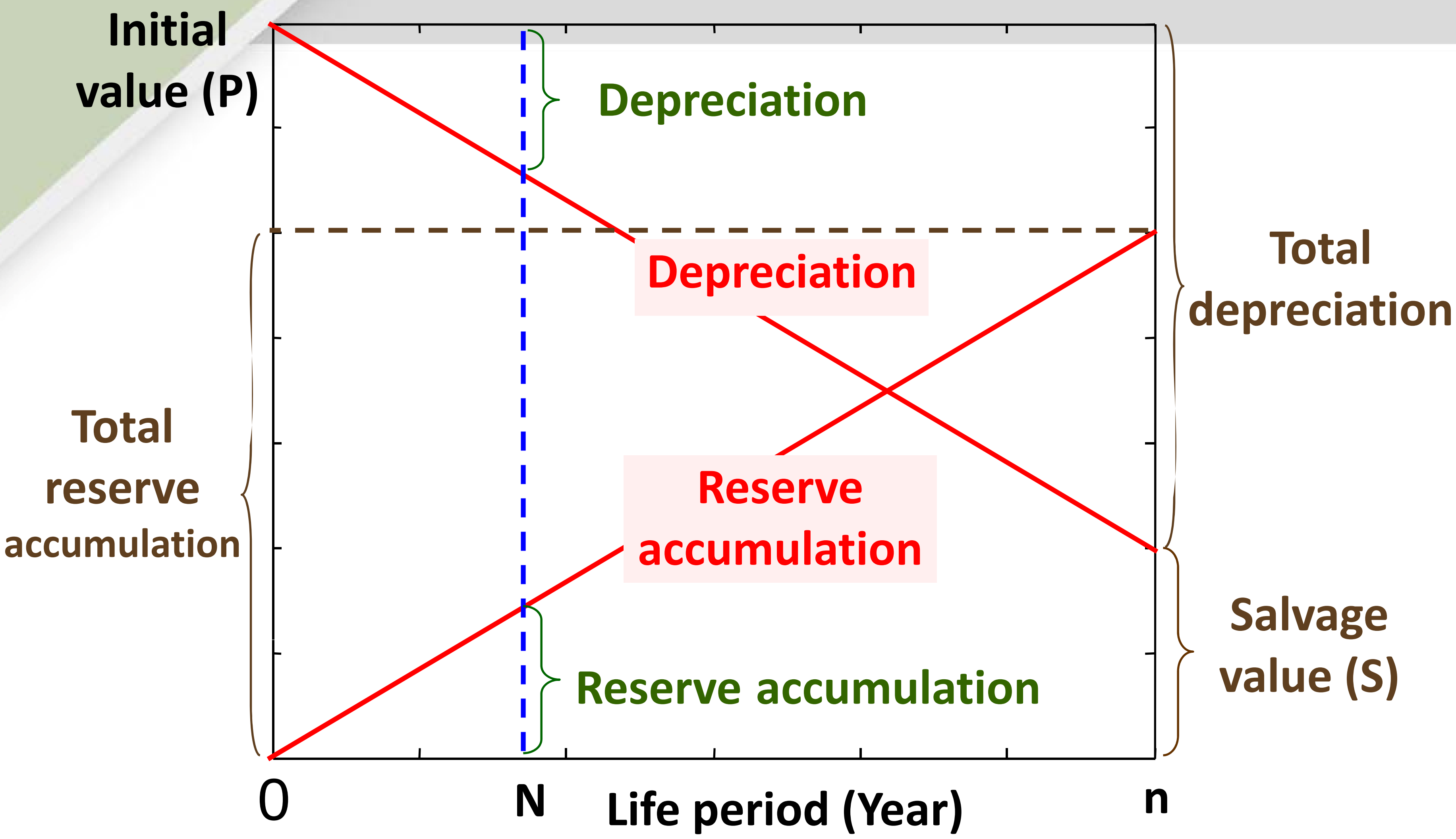
Straight line method



Straight line method



Straight line method



Straight line method

The straight-line method is the simplest approach to determine the depreciation cost of the power plant

It does not take into account the amount of interest earned by the set-aside money

A fixed annual amount is set aside each year

$$\boxed{A = \frac{P - S}{n}}$$

Diminishing-value method

The amount set aside per year decreases with the life of the equipment

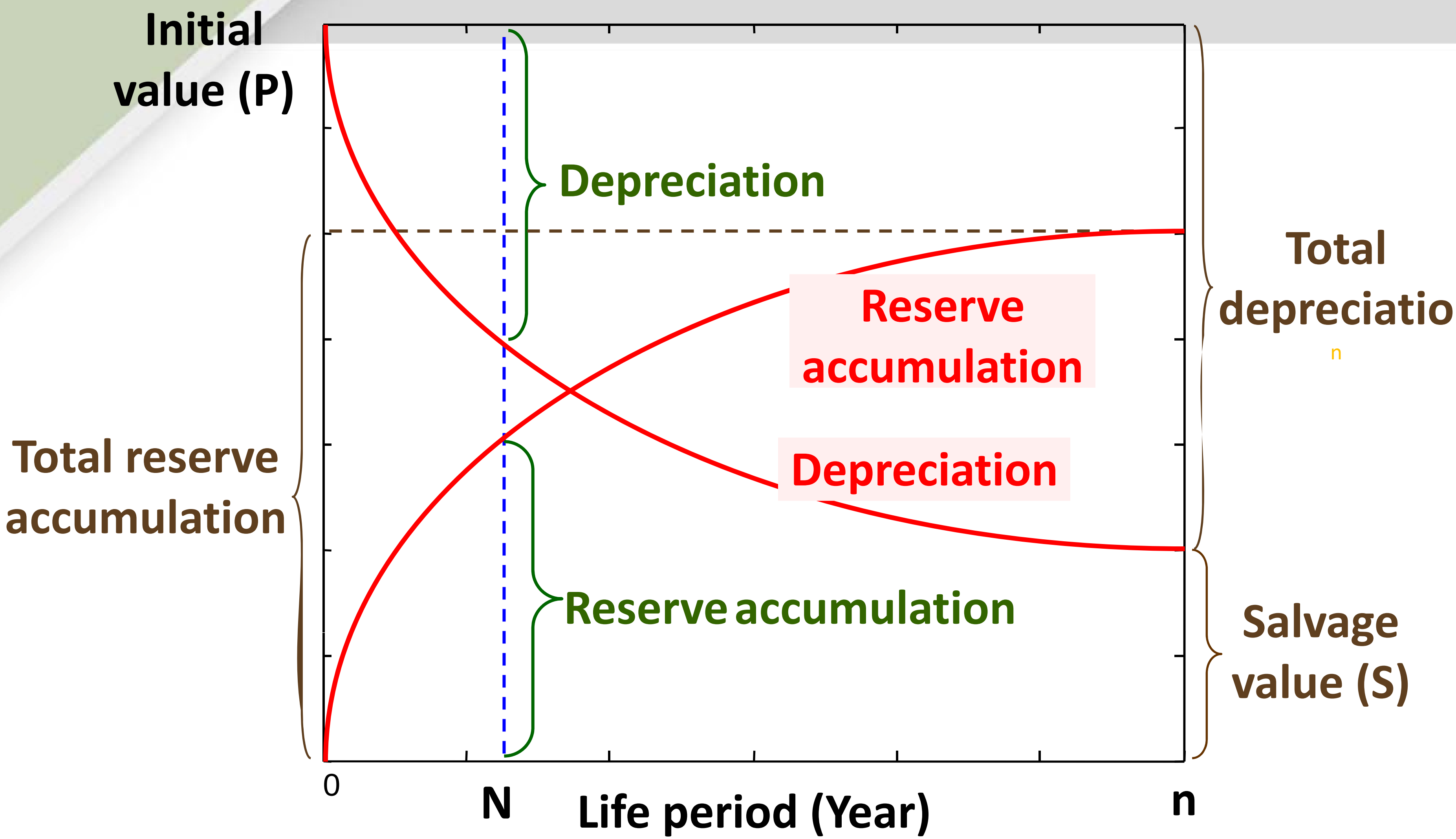
The total costs are distributed over the life since the depreciation charges are high in the first years where the maintenance cost and vice versa

A main disadvantage is the high charges in the first year, where the plant is still in the build-up stage

Instead of a fixed amount, *a fixed rate of depreciation* is applied, where the depreciation is applied firstly to the original cost and then to the diminishing value

The amount of interest earned by the set-aside money is ignored

Diminishing-value method



Diminishing-value method

The value of the equipment and the amount of set aside money per year at the end of each year are:

At the end of the:	Value of the equipment	set aside money
first year	$P - x \, . \, P = P \, . \, (1 - x)$	$x \, . \, P$

Diminishing-value method

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At the end of the:	Value of the equipment	set aside money
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Diminishing-value method

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At the end of the:	Value of the equipment	set aside money
first year	$P - x \cdot P = P \cdot (1-x)$	$x \cdot P$
second year	$P \cdot (1-x) - x \cdot P \cdot (1-x)$	$x \cdot P \cdot (1-x)$

Diminishing-value method

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first year	$P - x \cdot P = P \cdot (1-x)$	$x \cdot P$
second year	$P \cdot (1-x) - x \cdot P \cdot (1-x) = P \cdot (1-x)^2$	$x \cdot P \cdot (1-x)$

Diminishing-value method

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At the end of the:	Value of the equipment	set aside money
first year	$P - x \cdot P = P \cdot (1-x)$	$x \cdot P$
second year	$P \cdot (1-x) - x \cdot P \cdot (1-x) = P \cdot (1-x)^2$	$x \cdot P \cdot (1-x)$
⋮	⋮	⋮
n^{th} year	$P \cdot (1-x)^n$	$x \cdot P \cdot (1-x)^{n-1}$

Diminishing-value method

The value of the equipment at the end of the n^{th} year is equal to "S"
The annual unit depreciation can be calculated as:

$$P \cdot (1-x)^n = S \quad \Rightarrow \quad \boxed{(1-x) = \left(\frac{S}{P}\right)^{\frac{1}{n}}}$$

$$\boxed{x = 1 - \sqrt[n]{\frac{S}{P}}}$$